Impacts of Air–Sea Interaction on Tropical Cyclone Track and Intensity

LIGUANG WU

Goddard Earth and Technology Center, University of Maryland, Baltimore County, Baltimore, and Laboratory for Atmospheres, NASA Goddard Space Flight Center, Greenbelt, Maryland

BIN WANG

Department of Meteorology, School of Ocean and Earth Science and Technology, University of Hawaii at Manoa, Honolulu, Hawaii

SCOTT A. BRAUN

Laboratory for Atmospheres, NASA Goddard Space Flight Center, Greenbelt, Maryland

(Manuscript received 15 July 2004, in final form 19 April 2005)

ABSTRACT

While the previous studies of the impacts of air–sea interaction on tropical cyclones (TCs) generally agree on significant reduction in intensity and little change in track, they did not further explore the relative roles of the weak symmetric and strong asymmetric sea surface temperature (SST) anomalies relative to the TC center. These issues are investigated numerically with a coupled hurricane–ocean model in this study.

Despite the relatively small magnitude compared to the asymmetric component of the resulting cooling, the symmetric cooling plays a decisive role in weakening TC intensity. A likely reason is that the symmetric cooling directly reduces the TC intensity, while the asymmetric cooling affects the intensity through the resulting TC asymmetries, which are mainly confined to the lower boundary and much weaker than those resulting from large-scale environmental influences.

The differences in TC tracks between the coupled and fixed SST experiments are generally small because of the competing processes associated with the changes in TC asymmetries and the beta drift induced by air–sea interaction. The symmetric component of the SST drop weakens the TC intensity and outer strength, leading to a more northward beta drift. On the other hand, since the asymmetric component of the SST cooling is negative in the rear and positive in the front of a TC in the coupled experiments, the enhanced diabatic heating is on the southern side of a westward-moving TC, tending to shift the TC southward. In the coupled model the westward TCs with relatively weak (strong) outer strength tend to turn to the north (south) of the corresponding TCs without air–sea interaction.

1. Introduction

A tropical cyclone (TC) develops and is maintained by drawing energy from the underlying ocean surface. It can form only over waters of 26°C or higher and its intensity is very sensitive to the sea surface temperature (SST; e.g., Tuleya and Kurihara 1982; Emanuel 1986). Treating a tropical storm as a Carnot heat engine, Emanuel (1986) suggested that the TC maximum potential intensity is primarily determined by the underlying SST. At the same time, the surface wind stress associated with a TC can generate strong turbulent mixing that deepens the ocean mixed layer (OML) by entraining cooler water into the surface layer, leading to significant SST decreases. Observations indicate that the SST cooling caused by TCs ranges from 1° to 6°C (Price 1981).

The feedback of the resulting cooling on TC intensity has been investigated using coupled hurricane–ocean models. Early experiments were performed with upper OML models forced by axisymmetric TC models (Elsberry et al. 1976; Chang and Anthes 1979; Sutyrin and Khain 1979). Because of the markedly rightward bias of

Corresponding author address: Dr. Liguang Wu, NASA GSFC, Code 912, Greenbelt, MD 20771.
E-mail: liguang@agnes.gsfc.nasa.gov